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Scientific Paper

# Environmental and health risks associated with concentrations of metals in paint chips in Brazil

*Riscos ambientais e à saúde associados às concentrações de metais nas lascas de tinta no Brasil*

**Júlia Fonseca Colombo Andrade[1]*, Rodrigo Eduardo Córdoba[2], Valdir Schalch[1]**


## ABSTRACT

The presence of heavy metals in architectural paints poses a significant concern for environmental and occupational health. Research on the environmental and health risks of exposure to paint chips remains limited. In Brazil, no studies have examined the composition of paint chips from residential buildings and construction sites or their associated risks. Therefore, this study aimed to evaluate the presence of potentially hazardous metals in paint chips from renovation and demolition works in Brazil and identify the environmental and health risks to construction workers exposed to these metals. A total of 15 samples of household paint chips were collected and characterized by inductively coupled plasma-optical emission spectrometry (ICP-OES). Carcinogenic and non-carcinogenic risks were calculated according to the methodology of the U.S. Environmental Protection Agency (EPA) and considering workers' exposure through inhalation, ingestion, and dermal contact. Among the collected samples, one sample showed a lead concentration exceeding 600 mg/kg and two others had concentrations above 90 mg/kg. All samples contained cadmium at concentrations below 100 mg/kg. However, an outlier for lead was observed with hazard indices (HIs) above 1, indicating a potential health risk to workers. The study highlights a need for awareness of the risks associated with heavy metals in paint chips and the implementation of safety practices in the construction sector. Personal protective equipment (PPE), such as gloves, specific clothing, and masks, is recommended for reducing exposure to these hazardous metals, along with measures to prevent the dispersion of these chips and to ensure environmentally appropriate disposal.


**Keywords:** lead-based paint; occupational risks; environmental pollution.


## RESUMO

A presença de metais pesados em tintas imobiliárias representa uma preocupação significativa para a saúde ambiental e ocupacional. As pesquisas sobre os riscos ambientais e à saúde associados à exposição a lascas de tinta ainda são limitadas. No Brasil, nenhum estudo examinou a composição de lascas de tinta provenientes de edificações residenciais e canteiros de obras, tampouco os riscos associados a elas. Portanto, este estudo teve como objetivo avaliar a presença de metais potencialmente perigosos em lascas de tinta oriundas de reformas e demolições no Brasil e identificar os riscos ambientais e à saúde para os trabalhadores da construção civil expostos a esses metais. Foram coletadas e caracterizadas, por espectrometria de emissão óptica com plasma acoplado indutivamente (ICP-OES), um total de 15 amostras de lascas de tinta de residências. Os riscos carcinogênicos e não carcinogênicos foram calculados com base na metodologia da Agência de Proteção Ambiental dos Estados Unidos (EPA), considerando a exposição dos trabalhadores por inalação, ingestão e contato dérmico. Entre as amostras coletadas, uma apresentou concentração de chumbo superior a 600 mg/kg e outras duas apresentaram concentrações acima de 90 mg/kg. Todas as amostras continham cádmio em concentrações inferiores a 100 mg/kg. No entanto, um valor atípico de chumbo foi observado, com índices de risco superiores a 1, indicando um possível risco à saúde dos trabalhadores. O estudo destaca a necessidade de conscientização sobre os riscos associados aos metais pesados presentes em lascas de tinta e da implementação de práticas de segurança no setor da construção civil. Recomenda-se o uso de equipamentos de proteção individual (EPIs), como luvas, vestimentas específicas e máscaras, para reduzir a exposição a esses metais perigosos, além da adoção de medidas para evitar a dispersão dessas lascas e garantir sua destinação ambientalmente adequada.


**Palavras-chave:** tintas a base de chumbo; riscos ocupacionais; poluição ambiental.

## INTRODUCTION

The construction sector represents 6.2% of Brazil's gross domestic product (GDP) and is one of the sectors that generate the most formal jobs (Brasil, 2023). However, construction workers are exposed to various components that can cause health damage, e.g., particulate matter (Wang *et al.*, 2023), volatile organic compounds (VOCs) (Sekhar *et al.*, 2024), and heavy metals (Ceballos *et al.*, 2021).

Sources of metals in construction sites include use of welding, handling, and removal of paints, use of wood treatment solutions, as well as demolition or

[1]Universidade de São Paulo, Escola de Engenharia de São Carlos, Núcleo de Estudo e Pesquisa em Resíduos Sólidos – São Carlos (SP), Brazil.
[2]Universidade Federal de São Carlos, Departamento de Engenharia Civil – São Carlos (SP), Brazil.
***Corresponding author:** julia-colombo@hotmail.com
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renovation activities of buildings (Naylor; Davies; Gopaldasani, 2020). Paints, in particular, are significant sources of metals due to their composition, which often includes pigments, extenders, and metallic additives. For example, chromium is used for its anti-corrosive properties, whereas cadmium serves as a pigment in yellow, red, and orange colors and also provides heat resistance. Mercury, on the other hand, is used as a fungicide and bactericide (Puthran; Patil, 2023), and other metals (e.g., titanium dioxide, zinc sulfide, and zinc oxide) are widely employed as pigments in various paint formulations (Chen *et al*., 2022; Diebold *et al*., 2022).

Lead is commonly used in paints due to its advantageous properties, such as enhanced durability and improved surface adhesion and as a pigment (O'Connor *et al*., 2018). However, given the harmful effects of exposure to lead, the United Nations Environment Programme and the World Health Organization have established the Global Alliance to Eliminate Lead Paint, aiming to reduce such exposures by promoting a phase-out of lead-containing paints. By 2020, 39% of countries had implemented legal controls to regulate the production, import, and sale of lead-based paints (WHO, 2021).

In Brazil, Law No. 11,762 (Brasil, 2008), enacted in 2008, established a maximum limit of 0.06% (600 ppm) lead in residential paints, school-use paints, and varnishes manufactured, sold, and distributed in the country. However, paints violating this legislation are still sold (Clark *et al*., 2014), and construction workers often come in contact with paint chips manufactured prior to the implementation of these regulations during renovation and demolition works of buildings.

Metals present in paint chips and dust can directly enter the human body through ingestion, inhalation, and dermal contact and, depending on the level of exposure, can cause serious health damage (e.g., deficiencies in the development of brain and central nervous system in children, higher risk of hypertension and kidney damage in adults, reduced fertility, and increased chances of miscarriage and premature birth (Collin *et al*., 2022). The World Health Organization estimates that 30% of the global burden of idiopathic intellectual disability, 4.6% of the global burden of cardiovascular diseases, and 3% of the global burden of chronic kidney diseases in 2019 were caused by lead exposure (WHO, 2021).

Epidemiological research has shown that occupational exposure to cadmium may be associated with lung, stomach, kidney, and prostate cancers, cardiovascular diseases, diabetes, chronic kidney diseases, osteoporosis, and Alzheimer's disease (Chen *et al*., 2016; Bakulski *et al*., 2020; Zhong *et al*., 2021; Doccioli et al., 2024) and occupational exposure to hexavalent chromium is associated with an increased risk of lung cancer and respiratory diseases such as pneumonia and pulmonary fibrosis (Shin *et al*., 2023).

The International Agency for Research on Cancer (IARC) classifies arsenic, cadmium, chromium, and nickel as Group 1, i.e., carcinogenic to humans, and other compounds, such as titanium dioxide, as Group 2B, i.e., possibly carcinogenic to humans. This classification is based on sufficient evidence from experimental animal studies and inadequate evidence from epidemiological studies (IARC, 2024).

Given the various potentially hazardous components present in paints, this study chemically characterized samples of paint chips collected from renovation and demolition works and identified the health risks to construction workers exposed to such chips.

# METHODS

## Collection of paint chip samples

Paint chip samples were collected from 15 renovation and demolition sites in the southeastern region of Brazil. Construction and demolition waste containing paint as a finish was collected and stored in sterile plastic bags. In the laboratory, paint chips were removed with a spatula and then ground with a mortar and pestle until they could pass through a 0.075 mm sieve. Between 1 and 2 g of the sieved paint chips were placed into glass test tubes for mass characterization of their chemical element content.

## Chemical characterization of the samples

The paint chips were analyzed for concentrations of Al, Ba, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Ti, and Zn. The D 3718-85a protocol of the American Society for Testing and Materials (ASTMD, 2022) was adopted for the determination of Cr, whereas the D 3335-85a protocol (ASTMD, 2020) was applied for the analysis of the other elements. An additional step involving the heating of the sample with 1 mL of 50% nitric acid (v/v) on a hot plate was necessary for both protocols to evaporate organic solvents present in the paint chips. The direct digestion of the sample in a muffle furnace, as indicated in the protocol, led to explosions caused by the organic solvents in the matrix. Therefore, pre-heating in an acidic medium was essential to eliminate interference from these compounds.

The selection of the analyzed elements was based on a literature review, focusing on those commonly found in household paints. They were determined by inductively coupled plasma-optical emission spectrometry (ICP-OES) with the Thermo Scientific iCAP 6300 model.

## Health risk assessment model

The metals present in paint chips may pose health risks, particularly to workers involved in sanding and painting walls, as they are highly exposed to paint chips and dust. This study adopted the human health risk assessment methodology developed by the U.S. Environmental Protection Agency (US EPA, (2002) to evaluate these risks. The EPA model assesses the likely adverse health outcomes from exposure, the probabilities of individuals experiencing adverse health effects, and whether current exposure levels would pose a risk to human health.

### *Chronic daily intake*

The potential carcinogenic and non-carcinogenic health impacts due to exposure to metals from paint chips through inhalation, dermal contact, and ingestion pathways were calculated by the US EPA (2002) model, and the chronic daily intake (CDI) for ingestion, inhalation, and dermal exposure pathways was estimated by Equations 1, 2, and 3, respectively:

$$\mathrm{CDI_{ingestion}} = \mathrm{C} \cdot \left[\frac{\mathrm{R_{ing} \cdot EF \cdot ED}}{\mathrm{(BW \cdot AT)}}\right] \cdot 10^{-6} \quad (1)$$

$$\mathrm{CDI_{inhalation}} = \mathrm{C} \cdot \left[\frac{\mathrm{R_{inh} \cdot EF \cdot ED \cdot ET}}{\mathrm{(PEF \cdot BW \cdot AT)}}\right] \quad (2)$$

$$\mathrm{CDI_{dermal}} = \mathrm{C} \cdot \left[\frac{\mathrm{SA \cdot SL \cdot ABS \cdot EF \cdot ED}}{\mathrm{(BW \cdot AT)}}\right] \cdot 10^{-6} \quad (3)$$

The definitions and values of the variables used in Equations 1, 2, and 3 are presented in Table S1, in the Supplementary Material.

### *Risk characterization*

Non-carcinogenic health effects were estimated with the use of a hazard quotient (HQ) for ingestion, inhalation, and dermal exposure routes (Equation 4), and the hazard indices (HIs) for each potentially toxic element were estimated as the sum of the corresponding HQs, taking into account all exposure routes (US EPA, 2012) (Equation 5).

$$HQ = \frac{CDI_n}{RfD} \quad (4)$$

$$HI = \sum HQ = HQ_{ingestion} + HQ_{inhalation} + HQ_{dermal} \quad (5)$$

An HI greater than 1 indicates the presence of non-carcinogenic health risks and an HI smaller than 1 suggests that exposure to paint chips is not harmful (US EPA, 2004). Cancer risk (CR) (Equation 6) was assessed for As, Cr, Ni, and Pb since they are classified as carcinogenic by the IARC (2024). The total carcinogenic risk (TCRI) was estimated by summing the risks from each exposure route (Equation 7).

$$CR = CDI_c \cdot SF \quad (6)$$

$$TCRI = \sum CR = CR_{ingestion} + CR_{inhalation} + CR_{dermal} \quad (7)$$

The reference dose (RfD) values for each element and the slope factors (SFs) for the carcinogenic elements are provided in Tables S2 and S3, respectively, in the Supplementary Material. Regarding carcinogenic risk, if the CR or TCRI falls within the range of $1\times10^{-6}$ to $1\times10^{-4}$, it may indicate an acceptable or tolerable risk; however, if it exceeds $1\times10^{-4}$, the public may face a high CR (Liang, 2020).

### Statistical analysis

Shapiro-Wilk test was used to determine whether the concentration of metals in paint chips followed a normal distribution. The resulting p-values are presented in Table S4, available in the Supplementary Material. Spearman's correlation tests were applied due to the absence of normality in the concentration distributions of most analyzed elements.

## RESULTS

### Metals present in paint chips

Table 1 shows the concentrations of the metals assessed in the paint chip samples. Only sample P4, with a concentration of 1,183.96 mg/kg, exceeded the Brazilian regulatory limit of 600 mg/kg. According to the limit of 90 mg/kg adopted in other countries, such as the United States, samples P2 and P14 also exceeded the permissible levels, with concentrations of 275.90 mg/kg and 102.22 mg/kg, respectively.

Studies on the characterization and risks of paint chips in Brazil are still in the early stages. However, Clark *et al.* (2014) observed that paints sold prior to regulation contained an average of 36,000 mg/kg of lead––the maximum concentration found was 170,000 mg/kg. This indicates that lead levels in paint chips can be significantly higher than those found in the samples evaluated in this study.

Mielke *et al.* (2001) analyzed paint chip samples from 31 houses in New Orleans, USA, and reported lead concentrations above 100 mg/kg––the highest being 256,797.00 mg/kg––and cadmium concentrations ranging from 7 to 439 mg/kg in all samples. In contrast, the present study found cadmium concentrations below the 100 mg/kg limit set by the European Union (ECHA, 2012) in all samples, with the highest value being 8.79 mg/kg.

**Table 1 –** Metal concentrations in paint chip samples.

| | Parameters (mg/kg) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | Ba | Cd | Co | Cu | Cr | Pb | Fe | Mn | Ni | Ti | Zn |
| LOQ | 5.0 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 5.0 | 0.50 | 0.50 | 5.0 | 0.50 |
| P1 | 4,626.89 | 63.44 | 1.46 | 4.88 | 92.97 | 14.17 | 16.57 | 2,864.15 | 130.28 | 2.58 | 2,309.91 | 215.33 |
| P2 | 4,580.20 | 155.85 | 0.85 | 1.56 | 114.81 | 85.91 | **275.90** | 1,212.26 | 46.90 | 1.96 | 412.08 | 51.75 |
| P3 | 1,054.79 | 248.96 | 0.48 | 0.17 | 11.55 | 8.34 | 2.77 | 926.89 | 17.31 | 1.20 | 44.39 | 32.26 |
| P4 | 11,065.00 | 2,878.77 | 4.85 | 14.03 | 22.76 | 104.00 | **1,183.96** | 13,037.74 | 247.50 | 11.45 | 2,258.96 | 3,688.21 |
| P5 | 4,887.00 | 70.80 | 0.40 | 1.74 | 15.35 | 23.49 | 1.94 | 1,377.36 | 42.66 | 5.00 | 653.77 | 66.13 |
| P6 | 4,878.46 | 56.27 | 0.62 | 6.59 | 20.96 | 5.33 | 39.24 | 1,081.13 | 36.09 | 3.90 | 2,678.77 | 448.35 |
| P7 | 7,968.44 | 381.13 | 0.58 | 3.32 | 46.09 | nd | 24.34 | 6,047.17 | 216.65 | 3.26 | 1,413.68 | 131.98 |
| P8 | 15,365.13 | 196.65 | 0.07 | 5.64 | 16.56 | 12.08 | 4.36 | 2,670.75 | 265.90 | 3.21 | 2,979.72 | 128.54 |
| P9 | 2,573.92 | 127.64 | 0.24 | 0.20 | 95.61 | 11.71 | nd | 137.59 | 13.50 | 1.39 | 7.68 | nd |
| P10 | 1,053.82 | 132.64 | 0.50 | 0.64 | 16.23 | 4.54 | 27.42 | 691.04 | 12.92 | 1.45 | 374.06 | 23.72 |
| P11 | 13,524.92 | 1,037.26 | 0.44 | 3.27 | 45.87 | 23.73 | 21.17 | 5,174.53 | 139.25 | 5.26 | 943.87 | 3,878.77 |
| P12 | 1,268.49 | 71.04 | Nd | 1.06 | 20.17 | nd | 1.57 | 656.60 | 22.98 | 1.90 | 636.79 | 613.68 |
| P13 | 10,486.41 | 134.95 | 0.67 | 4.81 | 43.93 | 22.93 | 1.40 | 3,062.26 | 92.45 | 3.00 | 2,649.06 | 187.50 |
| P14 | 10,250.00 | 4,218.40 | 8.79 | 16.40 | 40.88 | 48.38 | **102.22** | 5,764.15 | 98.63 | 6.82 | 4,486.79 | 7,377.36 |
| P15 | 14,903.67 | 87.45 | 0.62 | 9.53 | 27.56 | 18.09 | 5.66 | 4,385.85 | 370.99 | 6.18 | 3,748.11 | 309.34 |

LOQ: Limit of quantification; Values exceeding the lead limit of 600 mg/kg and the USA limit of 90 mg/kg are highlighted in bold.
Source: Authors (2025).

Ogilo *et al*. (2017) evaluated paint chips in Nairobi, Kenya, and found lead, chromium, cadmium, and zinc at average concentrations of 289.59 mg/kg, 77.54 mg/kg, 73.45 mg/kg, and 366.14 mg/kg, respectively. In the present study, the average concentrations found were 113.90 ± 304.42 mg/kg for lead, 25.51 ± 30.87 mg/kg for chromium, 1.37 ± 2.36 mg/kg for cadmium, and 1,143.53 ± 2,142.36 mg/kg for zinc.

Inhalation of Cr(VI) increases both the incidence and risk of developing lung cancer, whereas ingestion through drinking water increases the risk of liver cancer (Wise Jr. *et al*., 2022). The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit of 5 $\mu g/m^3$ for Cr(VI) compounds in the air (OSHA, 2009), whereas the maximum allowable concentration of total chromium in drinking water by the World Health Organization (WHO) is 0.05 mg/L (WHO, 2021).

The concentrations of barium in the paint samples ranged from 56.27 mg/kg to 4,218.40 mg/kg. Although no specific regulatory limit has been established for barium in household paints, exposure to it is associated with several health issues, including cardiovascular, renal, metabolic, neurological, and mental disorders. Such associations are primarily based on studies conducted on animals (Kravchenko *et al*., 2014; Peana *et al*., 2021).

Similarly, titanium concentrations substantially vary, from 7.68 to 4,486.79 mg/kg. Although the relationships between occupational exposure to $TiO_2$ and mortality have not been fully elucidated, recent analytical approaches have rekindled concerns over the potential health risks associated with the compound (Hansa *et al*., 2023).

Iron is an essential micronutrient in several metabolic processes, including oxygen transport. Its deficiency can lead to anemia, but, on the other hand, the excess can cause damage to the liver, heart, and endocrine glands (McDowell; Chen; Sticco, 2024). Epidemiological studies have suggested that the inhalation of iron oxide is associated with increased incidences of cancer, cardiovascular diseases, and various respiratory illnesses (Morgan; Bell; Jones, 2020). Due to its variety of colors (yellow, orange, red, brown, and black), chemical stability, and low cost, iron oxides are widely used as pigments (Pfaff, 2021; Muehlethaler; Massonnet, 2023). In the analyzed samples, the iron concentration ranged from 137.59 to 13,037.74 mg/kg. The National Institute for Occupational Safety and Health (NIOSH) in the United States has established a recommended exposure limit of 5 $mg/m^3$ for iron oxide over a 10-h workday (New Jersey, 2007).

In addition to the health hazards associated with direct exposure to paint chips during wall scraping and building demolition, these chips can also pose risks to human health and the environment when dispersed in household dust or when contaminating soil and water. Doyi *et al*. (2019) evaluated the risks of exposure to household dust in homes in Sydney, Australia, and found that older homes (over 50 years old) with reports of peeling paint and no recent renovations had higher lead concentrations in household dust compared to homes of the same age without peeling paint, indicating paint chips are a significant source of lead in household dust.

Construction workers can also transport dust generated in their work areas to their homes, putting their families, especially children, at risk. Ceballos *et al*. (2021) observed that the homes of construction workers generally had higher and more variable lead concentrations in dust compared to the homes of sheet metal workers and janitors.

## Correlation between metals present in paint chips

The concentration of cadmium showed a positive correlation with chromium and lead levels (Table 2), suggesting that paints with higher concentrations may also pose increased risks due to elevated levels of other hazardous metals, such as chromium and lead.

Metals that showed the highest correlations were aluminum with barium (r = 1), cobalt with titanium (r = 0.93), aluminum with manganese (r = 0.89), barium with manganese (r = 0.89), and cobalt with nickel (r = 0.85). The high correlation between barium and aluminum may be due to the combined use of compounds containing these elements, such as barium sulfate (barite), which is frequently used as a filler in paints due to its opacity and resistance properties, enhancing the mechanical properties of the coating (Muehlethaler; Massonnet, 2023). Aluminum oxides are used as additives for improving both the durability and resistance of paints, and aluminum silicate (kaolinite) is used for improving mechanical properties and opacity and as a white pigment (Buyondo; Kasedde; Kirabira, 2022).

**Table 2 –** Spearman's correlation coefficient matrix (r) among the evaluated elements*.

| | Al | Ba | Cd | Co | Cu | Cr | Fe | Mn | Ni | Pb | Ti | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Al | | *≤ 0.001* | *0.53* | *0.002* | *0.667* | *0.066* | *0.002* | *≤ 0.001* | *≤ 0.001* | *0.658* | *0.002* | *0.045* |
| Ba | **1.00** | | *0.53* | *0.002* | *0.667* | *0.066* | *0.002* | *≤ 0.001* | *≤ 0.001* | *0.658* | *0.002* | *0.045* |
| Cd | 0.18 | 0.18 | | *0.017* | *0.164* | *0.038* | *0.024* | *0.259* | *0.103* | *0.007* | *0.089* | *0.17* |
| Co | **0.75** | **0.75** | **0.61** | | *0.695* | *0.107* | *0.002* | *0.002* | *≤ 0.001* | *0.076* | *≤ 0.001* | *0.004* |
| Cu | 0.12 | 0.12 | 0.38 | 0.11 | | *0.318* | *0.368* | *0.411* | *0.903* | *0.593* | *0.913* | *0.763* |
| Cr | 0.49 | 0.49 | **0.54** | 0.43 | 0.28 | | *0.048* | *0.128* | *0.028* | *0.179* | *0.229* | *0.331* |
| Fe | **0.76** | **0.76** | **0.58** | 0.35 | 0.25 | **0.52** | | *≤ 0.001* | *≤ 0.001* | *0.081* | *0.013* | *0.017* |
| Mn | **0.89** | **0.89** | 0.31 | **0.74** | 0.23 | 0.41 | **0.83** | | *0.004* | *0.314* | *0.004* | *0.052* |
| Ni | **0.79** | **0.79** | 0.44 | **0.85** | 0.04 | **0.57** | **0.81** | **0.72** | | *0.078* | *0.003* | *0.002* |
| Pb | 0.13 | 0.13 | **0.66** | 0.48 | 0.15 | 0.37 | 0.47 | 0.28 | 0.47 | | *0.340* | *0.182* |
| Ti | **0.75** | **0.75** | 0.45 | **0.93** | 0.03 | 0.27 | **0.64** | **0.71** | **0.73** | 0.26 | | *0.010* |
| Zn | **0.53** | **0.53** | 0.37 | **0.71** | 0.09 | 0.33 | **0.61** | **0.51** | **0.74** | 0.36 | **0.65** | |

*p-values in italics. Correlations above 0.5 are highlighted in bold, and significant correlations ($p < 0.05$) are underlined.
Source: Authors (2025).

### Assessment of health risk to construction workers

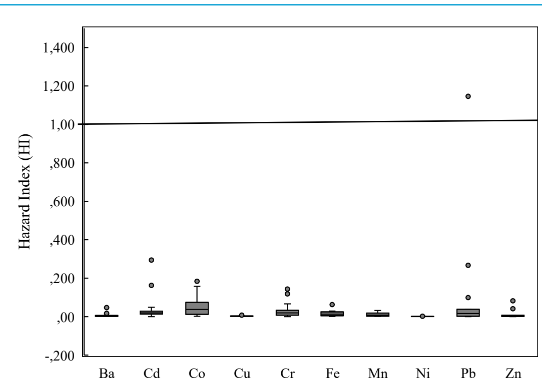
The non-carcinogenic risk associated with exposure to potentially toxic elements in construction workers was assessed with the use of an HI. Median HI values ranged from 0.00054 for nickel to 0.192 for cadmium (Figure 1). Although the upper limit of the HI for all metals analyzed remained below 1, lead showed an outlier with a value exceeding 1, which warrants attention. Both lead and cadmium are systemic toxins that can induce a range of diseases even at low levels of exposure (Shaffer; Gilbert, 2018; Rocha; Trujillo, 2019). Lead exposure is associated with neurobehavioral effects in children, as well as cardiovascular effects and nephrotoxicity in adults (Gundacker *et al.*, 2021). The main documented harms of cadmium exposure include renal dysfunction, increased risk of bone fractures, and lung cancer (Chen *et al.*, 2016; Lombaert; Gilles; Verougstraete, 2023).

Studies characterizing paints sold prior to regulation in Brazil have shown that construction workers exposed to paints containing lead concentrations of 170,000 mg/kg (Clark *et al.*, 2014). Furthermore, no studies in the country have comprehensively characterized paint chips, suggesting that these workers could be exposed to metal concentrations even higher than those reported in this study.

Ghaffarian-Bahraman *et al.* (2021) evaluated blood lead levels of building and car painters in Iran. The average concentration among all painters was 8.1 ± 4.93 µg/dL, whereas for building painters, it was 6.7 ± 1.85 µg/dL. The blood lead levels of 19% of the painters were above 10 µg/dL, a value considered high in adults by the United States Centers for Disease Control and Prevention (CDC, 2013). However, to date, no safe blood lead level has been established (Ruckart *et al.*, 2021).

CR was calculated for each exposure route, namely, ingestion, inhalation, and dermal contact (Figure 2a). For chromium, the ingestion route showed the highest risk, accounting for 82.69% of the total risk (Figure 2b). Inhalation of chromium-containing particles can cause lung cancer, whereas ingestion of chromium is associated with male infertility, kidney diseases, and gastrointestinal tract diseases (e.g., small intestine neoplasia and squamous cell carcinoma) (Shin *et al.*, 2023).

For nickel, dermal contact was identified as the route with highest total carcinogenic risk, representing 84.73% of its total. Nickel is the most common cause of contact dermatitis in both occupational and non-occupational settings and repeated and prolonged exposures to it can trigger an immunological hypersensitivity response in susceptible individuals, leading to reactions ranging from itching to severe eczematous skin lesions (Ahlström *et al.*, 2019).




Source: Authors (2025).

**Figure 1 –** Hazard index (HI) for potentially toxic elements. An HI greater than 1 indicates a non-carcinogenic health risk.

Although none of the analyzed elements or exposure routes showed values above $1\times10^{-4}$, which would indicate a high exposure risk, construction workers are still exposed to hazardous metals in their work environment. Therefore, it is essential that they wear gloves, protective clothing, and masks to minimize contact with construction materials. Additionally, they should avoid eating in areas contaminated with dust and paint chips and change clothes after leaving the workplace to prevent carrying dust and paint chips into their homes.

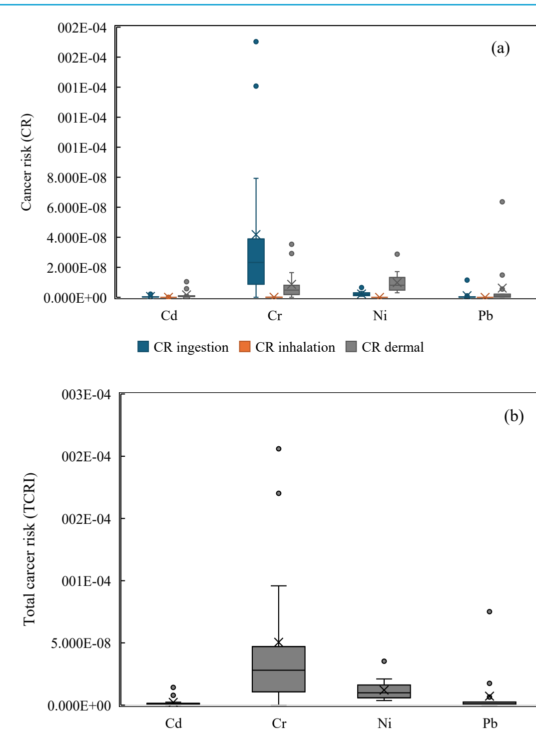
### Limitations and suggestions for future research

The risks associated with exposure to paint chips, especially from older buildings, have not yet been thoroughly explored. In Brazil, no studies have chemically characterized paint chips or assessed concentrations, bioavailability, and exposure risks to hazardous compounds present in them. Therefore, future research should focus on the following areas:

- Collection and characterization of a large sample of paint chips and evaluation of their environmental and health risks;
- Collection of dust samples from construction sites, assessments of environmental and health risks, and determination of whether paint chips are sources of hazardous compounds in the dust;
- Studies involving construction workers in Brazil and assessments of the presence of health damage due to occupational exposure.

## CONCLUSIONS

The paint chip samples collected from renovation and demolition sites in Brazil contained potentially toxic metals, such as lead, cadmium, and chromium,




Source: Authors (2025).

**Figure 2 –** (a) Cancer risk for each exposure route and (b) total cancer risk due to exposure to paint chips.

among others. Lead exceeded the Brazilian regulatory limit of 600 mg/kg in one sample and the American limit of 90 mg/kg in two other samples. Paint chips can contaminate soil and water, posing a health risk to those exposed to them. Although the upper limit of the HI for all analyzed metals remained below 1, there was a significant outlier for lead, suggesting a need for stringent preventive measures in the handling of paint chips.

The exposure of workers to metal concentrations significantly higher than those observed in this study is a concern. Although none of the analyzed metals and exposure routes showed a high CR, continuous exposure to these metals in work environments may result in serious health risks. Therefore, the use of personal protective equipment (PPE) and implementation of safe work practices and quality control policies are essential for reducing exposure.

This study also highlights the importance of ongoing and more comprehensive research in Brazil, including chemical characterization of paint chips and dust in several regions and construction contexts and investigation of health impacts on construction workers. The adoption of preventive measures and awareness of the dangers associated with exposure to heavy metals in paints are crucial for protecting the health of workers and the general population. Finally, future research should expand the sampling scope and deepen the analysis of environmental and health risks, contributing to the formulation of effective public policies and promotion of safer working environments in the construction industry.

## AUTHORS' CONTRIBUTIONS

Andrade, J.F.C.: Conceptualization, Data Curation, Formal Analysis, Methodology, Writing––Original Draft, Writing––Review and Editing. Córdoba, R.E.: Supervision, Writing––Review and Editing. Schalch, V.: Supervision, Writing––Review and Editing.

## DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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